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Flaw Restrained Flight Statistics Tailer Design

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Abstract: In the flight tracer project, the feasibility of transmitting data to ground station in real time is investigated. Instead of waiting for a prolonged time for locating the black box, the valuable information can be recovered instantly via stations. .With any airplane crash, there are many unanswered questions as to what brought the plane down. The answers are hid inside the black box and the teams are dispatched at a considerable cost to find it. The flight tracer project includes the distribution of area into segments and the subsequent communication between the plane and the ground station of the particular segment. A set of algorithms is developed to packetize the flight data, transmit it to the ground station and integrate the transmitted data to recover the flight information. We hope this work will contribute towards saving human lives and improving the safety and reliability of aircrafts.

Keywords: Black box, Distributed servers, Flight data

I. Introduction

The Aircraft Crashes Record Office (ACRO) a NGO based in Geniva announced that there are 2436 flight accidents all over the world fron 1999-2013 resulting in a death toll of 18,987. When flights meet disaster in the mid-air, the cause of the accident is not known immediately.

Teams are dispatched in difficult conditions to retrieve the Aviation data recorder also known as black box. Until the black box is found, the exact cause of the crash cannot be determined. Sometimes it may take years to find the black box. For example, Air France flight 447 crashed into the Atlantic Ocean on June 1, 2009. The cause of the accident remained unknown mainly because the black box was missing. It was found after almost two years in May 2011. It is important to note that the delay in finding the flight data recorder creates risks for future flights if the crash occurred due to a manufacturing defect in the model of the plane. The disappearance of Malaysia Airlines flight 370 demonstrated the limit of the contemporary flight recoder technology.

If the flight data is transmitted in real-time to the ground in addition to being saved in the black box, the data would be available instantly in case of a crash. This idea has been explored in the literature. In [2], the author discusses the feasibility of replacing the black box with “glass box", a term used to denote the communication system that would carry the flight data from the plane to the ground. Various communication medium alternatives are discussed and difficulties in arriving at a standard are outlined. In [3], the same author discusses intelligent agent based system design in which ground based intelligent agents would collect and analyze the flight data for identification of unsafe conditions. It is proposed to develop data mining techniques to alert the pilots of potentially unsafe conditions. In [4], a broad overview of the flight data recording and future transmission system is undertaken, including the notification from Bombardier of their proprietary transmission system to be introduced in C-series Jets in 2013. Recently WGL (Wireless Ground Link) from Teledyne [5] is released that is marketed to airlines as part of a package to monitor their fleet. Such solutions are not scalable and not targeted towards the global aviation and

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safety mechanisms. These modules can be added by the airlines to their planes in order to connect selected planes to ground for monitoring or fuel efficiency research. However, no software scheme has been presented in the literature for the development of flight data transmission system that targets and utilizes the aviation infrastructure for a general scalable and ubiquitous solution.

II. What Is Flight Tracker

In this section, the overall structure of the proposed distributed flight tracker is described. The structure of the system is depicted in Figure 1. An elaborate system is proposed consisting of one plane server, one controller server and several distributed servers on the ground. Flight tracker can be described as a real time software system for transmitting and tracking aviation data through distributed servers for rapid after-crash retrieval, real-time alerts and data mining for operational efficiency.

There is a great need for tracking flights in real-time. There are obvious advantages in finding the data instantly after a plane crash instead of waiting for several days until the black box is found. The real-time nature of this system makes it extremely useful for ground based monitoring of flights. Real-time data would avoid situations such as the Northwest Airlines Flight 188 on October 22, 2009 that missed the airport by 150 miles. The engine temperature, fuel pressure, heading, altitude and other data can trigger alarms to alert pilots if values exceed safety thresholds. Such real-time alerts could avert disasters such as the Colgan Air Flight 3407 that crashed near Buffalo, NY in Feb 2009. The transmitted real-time data can be stored for long time and data mining techniques can be used to derive useful results to improve the fuel efficiency.

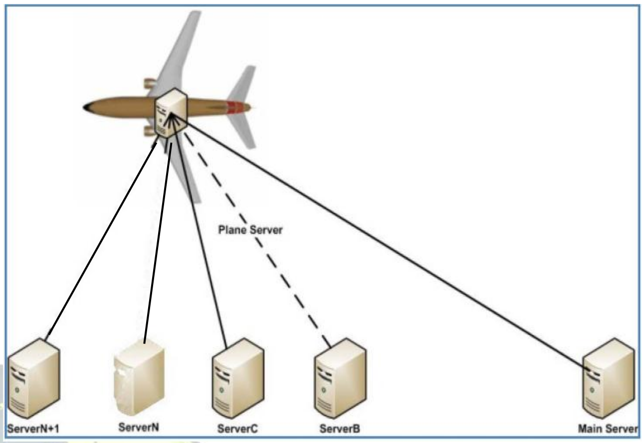

Figure 1 Plane Server, Small Servers and Main Server During Flight

The Flight Tracker project includes a distributed fault tolerant handshaking and data transmission protocol and header formats for communication between plane and ground servers. A set of algorithms is developed to packetize the flight data, transmit it to the ground to an array of servers and integrate the transmitted data to recover the flight information.

When the plane server initializes, the Flight Tracker system contacts the main server at the origin control tower, and conveys flight information. In response, the main server provides the list of data servers that would be on the route to the destination airport. The plane server performs handshake with the data servers and starts transmitting the data. The data is received by each data server, optionally archived in. Its storage and forwarded to the main server at the origin airport. At the successful completion of the flight, the main server at the origin airport (or alternately destination airport) has the complete flight data just like the black box in the plane.

No re-training of flight crew is needed in deploying the Flight Tracker as the system is fully automated. No major modification is needed as the data is already in digital format and the plane has the VHF radio and satellite connections with sufficient bandwidth. Modern network bandwidths are sufficient to handle this small constant rate flow of data to the ground. This system is scalable as each flight's path determines the main server and distributed ground servers that would get the data through VHF radio or satellite. The amount of data, the constant rate nature of the transmission, the distributed servers involved in

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data reception and the time window of transmission are highly predictable, thus resulting in efficient planning and commitment of resources.

The potential market for this system consists of airlines, The Boeing Company, Airbus, Bombardier, and black box manufacturing companies. The implementation of this technology will contribute towards saving human lives and improving the safety and reliability of aircrafts.

III. PLANE, MAIN AND DISTRIBUTED SERVERS

Main server has two major responsibilities. First one is to create a list of small servers that the plane will be going through with respect to its route. This list is sent to the plane and distributed servers alerting them to the approximate time of plane arrival in their zone. Second responsibility is receiving messages from the data servers. The messages contain flight data that will be integrated in the main servers. The major steps in the main server algorithm are shown in Figure 2.

```
Main Server
              S
        tart:
        Receive
        msg;
        determine
        source [f
        (msg
        ==
        ONLINE)
        then
            a.    Send ACK
            b.    Send ROUTE
            QUERY
            c.    Get ROUTE info;
            d.
            HANDSHAKE
            with small servers
            on route e.     Send
            list of small servers
            on route to plane
       else
            a.    extract DATA
            from msg
2.          b.  check packet
            number; if
            duplicate discard
            c.   else save
            DATA in buffer
   End
```

Figure 2 Main Server Algorithm During Flight

In addition to the control and data packets, main server may optionally receive heartbeat messages from the data servers and planes. If the message is identified as "CO", it is the initial message from a plane. An acknowledgement and a request for the route is sent back. Based on the next message, if the route is sent, a list of small servers is created with respect to the route indicated in the message. If it's not a route message, request for the route is periodically sent. Message type codes are embedded in the headers and their meanings are indicated in Table 1.

If the message received by the main server is a DA message, it is sent by one of the data servers and consists of flight data. Since the flight duration and arival time is set on take-off, packets containing the flight data may be pre- numbered. This feature lets main server decide whether the packet is new or redundant. Packets carrying the flight data received for the first time will be saved. Flight data is integrated and made available by the main server for data retrieval and analysis after the completion of flight message is received from the last server in the list. If the flight could not be completed due to a disaster, the flight data would be invaluable in determining the cause of the disaster in a very short time.

Message	Message Code Explanation
CO	Initial handshake packet from the plane to the main server
RQ	Route query from the
RP	Destination identification from the plane to the main server

SL	Message from the main server to the plane identify ing the data servers on the route
DP	Flight data packet from the plane to the data server
CP	Flight completion packet from the plane to the data server
DA	Flight data packet from data servers to the main server
CL	Flight completion packet from data servers to the main server

Table 1 Message types in Flight Tracker

containing flight information to the data servers. There are two types of packets sent by the plane server, control and data. The first one is CO type message, which means the plane is ready for flight and waiting for the route list. The second type is the regular packet containing flight related data. Plane saves values of the parameters in its send buffer but some of the parameters values are not frequently updated because of their nature. For example, in auto-pilot mode, the peed may be constant for a long time. For such type of data, interval timer can be used. Timer can be set for specifIc amount of time. If the timer runs out, the parameter value is sent whether its value is changed or not.

Plane server's second responsibility is being able to assign itself to the data servers to send data and change the data server in use when needed. As the data servers are only capable of receiving data in a limited area, plane must change servers from time to time. This function is done by usmg the server l and time values that indicate the relative distance from the data servers if direct VHF radio communication channel is used. If the communication is via satellite because the plane is flying over ocean or desert virtual data servers can be used to distribute the data.

At take-off, the location and number of distributed data servers is calculated. Due to unforeseen circumstances the flight may not reach the server zones at the exact precalculated time. It is therefore important to build an algorithm that pings the data servers periodically and changes the destination of data. This algorithm is shown in Fig3. A control message is sent to the current data server which is assigned to the plane and represented by ServerC and to the next server which is the next server in the list of servers represented by ServerN. If the control message is lost on both servers for ten consecutive attempts, it is assumed that there is a communication problem and the algorithm returns, triggering re-connection attempts at another level.

Otherwise, round trip time is calculated based on the results of the control message. Tl represents the round trip time for the ServerC and the T2 represents the round trip time for the ServerN. If Tl's value is larger than T2's value a server change is made. ServerN becomes the new ServerC and the server after the ServerN in the list replaces the curent what happens if only one server responds to the control message. Server N as shown in Figure 3 algorithm also shows

Changing Server

Start:

1. Assign ServerC = current server; ServerN=next server in line and PingCount = 0;
2. Ping ServerC and ServerN
3. If ping response received from both servers then a. Assign TI = ServerC response time
   b. Assign T2 = ServerN response time c. If (TI > T2) then
   i. Assign ServerC = ServerN
   ii. Assign ServerN = ServerN+I
4. else
   a. if ping response received from ServerN then i. do steps 3.c.i and 3.c.ii

then
i. PingCount = PingCount+I
ii. If (PingCount = 10) then send PANIC to Main Server
iii. else go back to step 2

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End

Figure 3 changing server Algorithm

Distributed data servers, located in the aviation facilities on the flight route, receive the control packets from the main server or data packets from the plane and direct them to the main server for assembly and archiving. The data server performs handshake with the main server for keeping a soft state for a flight. Data server receives a data message from the airplane, sends an acknowledgement and checks the packet sequence. If the newly received packet sequence number matches an already received packet, it is discarded, else the packet is saved. Each packet is identifIed with the black box ID# and the destination of the flight. In addition to saving the data packet locally, its copy is forwarded to the main server controlling the current flight.

IV. IMPLEMENTATION OF FLIGHT TRACKER

The flight tracker has been implemented on Linux problem for test and simulation purposes. Curently the distribute algorithms are fully designed and prototype software m C language is functional on multiple Linux servers. The system consists of main server (mainserver.c), plane server (plane.c) and a set of data servers (dataserverN.c where N designates the sequence number of the data server). Flight tracker algorithms and code are protected under US provisional patent and copyright filled by SUNY Research Foundation. Version 1.0 allows control messages and data transfer between plane and main server. Version 1.1 removes command line arguments and binds servers to fIxed port numbers for automated simulation runs. Version 2.0 and 3.0 introduce data servers that receive data packets from the plane server and complete the data transfer from the plane server to the data and main servers. Version 4.0 expands the system functionality by allowing creation of data files by data and main servers. Version 5.0 allows bypassing faulty servers through communication failure detection and migration to the next server.

V. INTRODUCING FAULT TOLERANCE

The flight tracker is designed to be fault tolerant to avoid any problems in working with many servers. The system works with one airborne server, one ground based control server and several ground based data servers. Therefore, it is imperative that the system continues to work even if faults are developed in any of the multiple servers.

Fault tolerance is achieved by decoupling the lower level communication from the upper level programs. The system utilizes a separate module to continuously test the connectivity of the airborne server to the ground based facilities. In case of any serious problem in communicating with the curently selected ground based server, the system moves on to handshake with the next server in line in order to continue the transmission.

It shows the scenario of a flight from Buffalo NY to Chicago IL. This flight has marked four data servers on the ground namely London (Ontario), Detroit (Michigan), South Bend (Indiana) and Chicago (Illinois). The control server can be located at Buffalo NY (Origin) or Chicago IL (destination). The S2 data server at Detroit could not be contacted by the plane and after repeated attempts, it moves on to select the next server in line. Since the communication to the nearest server was through VHF radio link, the communication failure would mean that S3 would be automatically connected via SATCOMM since S3 is currently too far to be accessible by the radio link. The plane server is a process which can be duplicated for redundancy as it can be configured to run off the black box or the central gateway node inside the plane. Both the black box and the gateway node are capable of running the plane server process thus PLR (Process Level Redundancy) can be implemented for obtaining fault tolerance for the plane server.

Another feature relates to the update frequency for certain type of data. Since some data is constant over a long period of time, sending it repeatedly is a waste of resources. For example, heading and speed of the aircraft, outside temperature and altitude above the ground may remain constant in long flights during auto-pilot mode. Therefore, timers can be associated with such data so that new values are sent only when they change abruptly or if the timer runs out. Fault tolerance is achieved in data storage as each data server keeps its copy of the data as well as forwards it to the main controller server that assembles complete data at

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touchdown of the aircraft and makes it available for data mining and post flight analysis. Therefore backup storage of data is available for 12 to 24 hours at the distributed servers.

VI. After Malaysian Airline Flight

370: On March 12,2014 the Malaysian Airlines flight 370 went missing with its black box no where to be found. The lack box sent strong pings until the first three weeks after which it is assumed the battery died out. The real question to be put forward is to be put forward is 'do we really should depend entirely on the black box when the technological advancements are on its peak? The idea to initiate satellite communication has been brought out since the Air France Flight, which took 2 years for its black box to be located, yet it hasn't been implemented due to high cost factor. The satellite communication need not transmit all the information from the black box on an hourly basis. The signals can be sent forth when a disturbance occurs consequently reducing the overall cost. Also, deployable black box would have resulted in the recoder floating on the surface of water rather than under layers of debris. The recent mishap has brought forth the limitations of the present black box. Modification are necessary to reduce the loss of precious human lives and machinery.

VII. Conclusion

In this article, the work done to develop a Defect forbearing system for transmission of flight data to ground in real-time is reported. Although real-time flight data transmission has been discussed in the literature, no implementation has been carried out yet. In flight tracker, a three tier system is specified in which the distributed data collection servers are controlled by the main server that coordinates with the plane server for flight data transmission. A protocol and packet types are defined to accommodate all from current limit of 30 days to atleast 90 days. Deployable recoder or distress radio beacons can be used which automatically activate upon immersion and send out a distress signal. Future work also includes adding encryption and routing. Modules in the system to enable it to handle real flights. Data mining of received data on flight completion may be performed for analysis of fuel efficiency and warning signs.

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